REMEDIATION OF CONTAMINATED INDUSTRIAL LAND: A COMMUNITY SOLUTION TO A LOCAL ENVIRONMENTAL PROBLEM

Sheryl Stivens, WasteBusters Trust Canterbury, P.O. Box 323, Ashburton.
Tel: (03) 308 9998, Fax: (03) 308 9989, Email: sherylstivens@clear.net.nz
Dr. Steve Kroening, NexGen Composting Ltd, Email: s.kroening@nexgencomposting.com
Mike Daly, New Zealand Nature Farming Society, Email: naturefarm@xtra.co.nz

Introduction

Wool scouring (wool washing) is a process whereby contaminants on the wool fibre, which include grease (the solvent-extractable fraction), suint (the water-soluble fraction), dirt (including dust, faecal matter, sand and mud) and vegetable matter are removed to allow further processing of the wool (Stewart, 1988). It is easily the most polluting stage of wool processing (Russell, 1996c), with a typical wool scour plant producing an effluent with a chemical oxygen demand approximately 50 times higher than that of domestic sewage (Bateup et al., 1996).

Since wool scouring is a process by which the contaminants are removed from the wool and transferred to the wash water, principles of waste minimisation are not possible (Bateup et al., 1995, Russell, 1996a). In general, increasing environmental awareness and legislation has changed the way waste streams from wool scours have been handled, but the location of a scour and local environmental regulations have dictated what treatment systems have been installed to meet the discharge problems associated with the effluent (Hoffmann and Timmer, 1996, Russell, 1996a). In Australia and New Zealand, where there is an abundance of land and clean water, and with most cities located on the coastline, scours have not faced the same problems as those located in Europe, which tend to be clustered together on inland river systems (Russell, 1996a).

The Ashburton Wool Scour, a small installation that processed a lot of low micron merino wool, closed at the end of 2005, leaving behind contaminated sludge and other fibrous wastes at various locations on site. Figure 1 shows the location of the site from the Environment Canterbury (Ecan) GIS mapping service. The sludge contains wool grease, which will in turn contain detergent and pesticide residues used at the time, as well as dirt. Figure 2 shows (a) the main sludge pond containing approximately 1,700 m^3 'old' sludge, (b) sludge in the drainage channel that extends to the Ashburton River, (c) concrete bunkers containing approximately 300 m^3 of 'new' sludge and fibrous wastes, and (d) a wastewater treatment plant installed by ANDAR Holdings Ltd (whom NexGen is a subsidiary of) in 2002.

The wool scour building has now been demolished and the site is being developed as a new industrial park. As part of this process the sludge remaining on site must be dealt with. Seeking an alternative to disposal of this material at Kate Valley landfill, Davis Ogilvie and Partners Ltd, the consultants working with Woodhams, owners of the site, contacted Dr. Steve

Kroening at NexGen Composting Ltd and WasteBusters Trust Canterbury to come up with a local solution. Kroening's Ph.D. research (Kroening, 2003) investigated the composting and land application of wool scour waste products, part of which was conducted at the Ashburton Wool Scour site. He has also undertaken consultancy at a number of scours around the world. WasteBusters are local composters with an excellent reputation for the quality of their composting processes earned through more than two years of operation at the Ashburton Resource Recovery Park. Approval for the project was sort from, and granted by, Ecan.

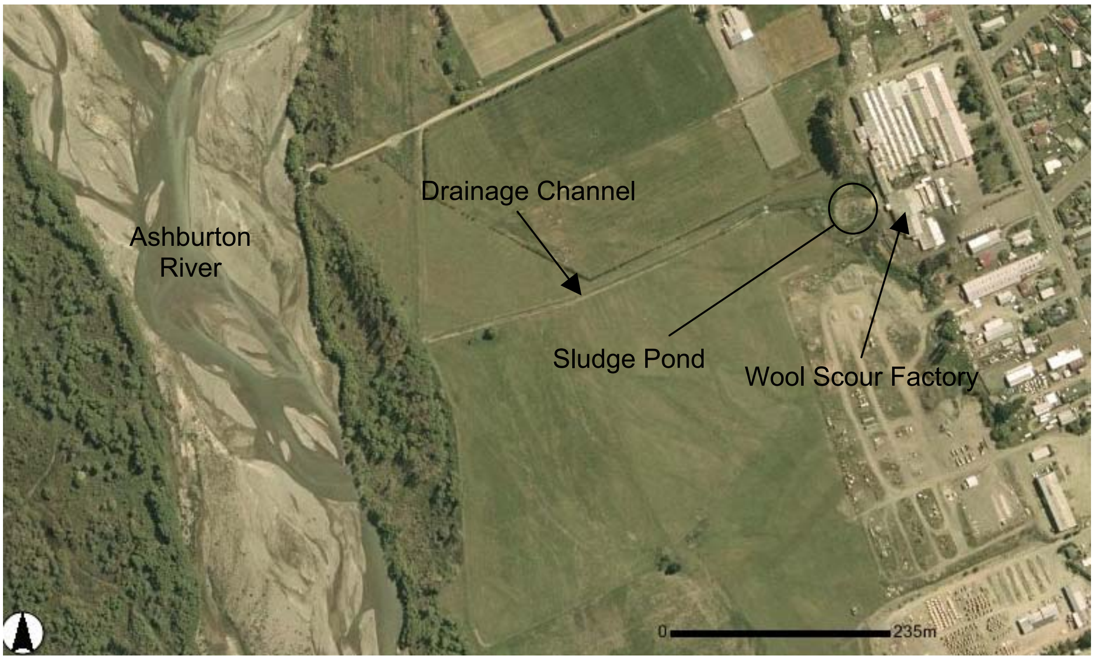

Figure 1.

Figure 2(a)

Figure 2(b)

Figure 2(c)

Figure 2(d)

Some research has been previously conducted into the composting of woolscour wastes. Williamson (1998) used a small-scale forced air static system but had limited success probably due to technical problems with the system. Geelong Wool Combing in Australia had a zero waste policy and composted their sludge up until their recent closure (Maheswaran et al., 1999). Kroening visited their operation in 2001 and provided assistance with their process, whereby they composted 10,000 tonnes per year sludge with 11,000 tonnes per year pine sawdust. Computer-controlled mixing was important to their consistency of operation, with thermophilic temperatures (up to 70ºC) achieved within 24 hours in windrows measuring 200-300 m in length, 1.5 m in height and 5 m in width. Until it is degraded, the wool grease acted as a binder. Total composting duration was 16 weeks at which time a garden supplier purchased the finished material under contract. The biological treatment of fats and oils at thermophilic temperatures is expected to be advantageous due to favourable changes in most physical properties of these compounds (Becker et al., 1999). In the liquid form, these compounds become more accessible to microorganisms and their lipolytic enzymes.

The ‘new’ sludge illustrated in Figure 2(c) was produced by the ‘Sirolan CF’ process commercialised by ANDAR Holdings Ltd, which uses the addition of acid and a polymer combined with a centrifuge to separate as much as possible of the grease and dirt from the waste water and produce a spadeable sludge. Research by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) illustrated the compostability of this sludge, as judged by the establishment of thermophilic temperatures and degradation of wool grease, when mixed with bulking materials and composted in static piles (Bateup et al., 1996, Jones and Westmoreland, 1998, Jones and Westmoreland, 1999). Kroening’s research (Kroening, 2003, Kroening et al., 2004) further investigated the rates of decomposition of this sludge and its constituents in both lab-scale and pilot-scale work. On a commercial scale, Kroening assisted with the establishment of composting of sludge from the Kaputone Wool Scour in Christchurch by Canterbury Landscape Supplies, who use an identical mixer manufactured by NexGen and produce an excellent topsoil material now available for sale.

The overall objective of this project was to compost the sludge remaining on the wool scour site to the requirements of New Zealand Standard NZS 4454:2005 (Standards New Zealand, 2005) and produce a saleable product, thereby avoiding the need for transport to and disposal at the Kate Valley Landfill approximately 170 km away.

Trial Methodology

Partners in the project were as follows:

- WasteBusters Trust Canterbury, project management and supervision of daily operations;
- Grant Hood Contracting, excavation of sludge, blending of materials and windrow formation and turning;
- NexGen Composting Ltd, manufacture of the mixer and provision of technical assistance; and
- New Zealand Nature Farming Society, supply of Effective Microorganisms (EM) and technical assistance associated with its use.

The project was to be conducted in two parts. Firstly, the estimated 1,700 m^3 sludge in the main pond was to be excavated and treated. Secondly, the material in the drainage channel and concrete bunkers (estimated at 300 m^3 each) could be treated. The following methodology was developed and approved by Ecan:

- Transport of 3,400 m^3 compost from the WasteBusters site to the composting site for use as the bulking agent;
- Excavation of the estimated 1,700 m^3 sludge from the main pond;
- Manufacture and supply of a 4 m^3 batch mixer by NexGen to blend the materials and add EM for odour control and increase degradation;
- Formation and regular turning of windrows using a front-end loader;
- Testing at eight weeks by Hill Laboratories and the University of Canterbury to show compliance with NZS 4454 and determine residual grease levels; and
- Transport of finished screened compost back to the WasteBusters Resource Recovery Park for sale.

Sludge in the main pond was tested by Davis Ogilvie and shown to contain 200,000 mg/kg grease (20% by weight). Material was dug from the pond and mixed with bulking agents, including coarse greenwaste compost and compost produced from lawn clippings and gypsum, at a ratio of approximately 2.5 volumes bulking materials to 1 volume sludge. This ratio varied with the moisture and grease contents of the sludge to ensure the mixed material was friable and therefore able to be passively aerated. Mixing time was approximately 2 minutes with the addition of 3 L per batch EM through a pump and spray system fitted to the mixer by NexGen. Table 1 illustrates the properties of the feedstocks composted.

EM technology was developed in Japan in the 1980's and consists of mixed cultures of beneficial and naturally occurring organisms, primarily lactic acid bacteria, yeast and photosynthetic bacteria, but also actinomycetes and other microorganisms (Naturefarm Limited, 2007). EM is already in use at composting operations in Ashburton and Christchurch where improvements in organic matter decomposition and odour control have been observed.

Table 1. Properties of the feedstocks.

Feedstock	Moisture (%)	pH	Density (kg/m^3)
Grass Clipping Compost	32-45	6-7	600-730
Greenwaste Compost	40-53	6-7	320-440
Sludge	44-64	6-8	920-1,140
Initial Blend	40-50	6-7	600-750

Windrows were formed to a maximum height of 2 m and width of 5 m, labelled for tracking purposes, and periodically checked for temperature and moisture. Figure 3 shows (a) excavation of the sludge from the pond, (b) the sludge mixer manufactured by NexGen, (c) the blended material for composting, and (d) the windrows formed on the composting site.

Figure 3(a)

Figure 3(b)

Figure 3(c)

Figure 3(d)

Trial Results and Discussion

At the time this paper was assembled the composting process was still underway and had not reached the testing stage. Temperature profiles and observations of materials in the windrows were all extremely positive. Temperatures in the windrows heated up to above 55ºC within one week (peaking at 70ºC), illustrating the blend of materials were suitable to composting.

The sludge was quite variable in its consistency, due to variation in both the moisture and grease contents, and was also influenced by climatic conditions of temperature (including the odd frost) and humidity. The mixer operator had to monitor the output from the mixer and adjust the ratio of bulking materials and sludge as required. The sludge was successfully coated onto the bulking materials when the mixer was loaded first with bulking materials, then sludge, then further bulking materials. The lag time between starting and thermophilic temperatures would have been reduced through active microbial populations already present in the bulking materials and through the addition of EM. Upon turning the windrows little odour was released; a faint wool smell was detectable.

It was important to limit the height of the windrows due to the density of the sludge and its effect on the density of the overall blend. Any compacted areas showed sluggish temperature development compared to other parts of the windrows. Heat transfer through the windrows appeared to be more horizontal than vertical, reflecting the density of the sludge.

Figure 4(a)

Figure 4(b)

Figure 4(c)

Figure 4(d)

With no water available on site, maintaining moisture levels in the windrows was the biggest challenge. Turning of windrows was coordinated with expected precipitation (including snow on one occasion!) when possible to replenish moisture levels, which were maintained at around 40%. After four weeks of composting it was difficult to detect sludge in the windrows. The absence of grease in the finished material will be confirmed through testing (Soxhlet extraction) at the University of Canterbury. Figure 4 shows (a) the sludge excavated from the pond, (b) the grass clipping compost, (c) the coarse greenwaste compost, and (d) material from the windrows after four week of composting.

Future Work

At the time this paper was assembled, WasteBusters were still in negotiations to carry out the second part of this work; this being the material located within the drainage channel and concrete bunkers. Analysis of this material was provided by Davis Ogilvie (Table 2). With reference to the New Zealand Biosolids Guidelines (New Zealand Water and Wastes Association, 2003), zinc was found at levels exceeding the Grade ‘a’ contaminant limit of 300 mg/kg that applies after 31/12/12. Dieldrin levels in some samples also exceeded the limit of 0.02 mg/kg.

Table 2. Analysis of material in the drainage channel.

Parameter	Unit	Pond Sediment	Drainage Channel
Arsenic	mg/kg	4-6	5-8
Cadmium	mg/kg	0.2	0.1-0.3
Chromium	mg/kg	17-19	26-39
Copper	mg/kg	42-46	21-29
Nickel	mg/kg	10-13	12-16
Lead	mg/kg	21-23	20-31
Zinc	mg/kg	417-453	375-647
Total N	g/100g	1.67-2.28	0.49-1.11
Nitrate-N	mg/kg	< 1	< 1
Oil & Grease	mg/kg	29,900-37,600	102,000-122,000
DDD[1]	mg/kg	< 0.01	< 0.01-0.01
DDE[2]	mg/kg	< 0.01-0.01	0.02-0.05
DDT[3]	mg/kg	< 0.01	< 0.01
Total DDT[4]	mg/kg	< 0.01-0.01	0.02-0.06
Dieldrin	mg/kg	< 0.01-0.02	0.02-0.04

DDT and dieldrin are persistent organochlorine pesticides whose use had effectively ceased in New Zealand by the mid 1970’s (Ministry for the Environment, 2007). They are now banned in most countries (EXTOXNET, 1996, Wikipedia, 2007). The types and amounts of pesticide residues in the sludge depend on the parasites treated and the time between treatment and wool harvesting (Jones, 1997, Russell, 1996c), with organophosphates and synthetic pyrethroid types now most widely used in New Zealand (Williamson, 1995). A large drop in fleece dip residue levels in Australia and New Zealand was observed in the mid-1990s due to

[1] Dichlorodiphenyldichloroethane, a breakdown product of DDT.
[2] Dichlorodiphenyldichloroethylene, a breakdown product of DDT.
[3] Dichlorodiphenyltrichloroethane.
[4] DDT + DDD + DDE.

improved farming practices whereby the time between dipping and shearing was increased (Christian, 1998, Russell, 1996b, Russell, 1996c).

From Kroening's research (Kroening, 2003), the 'new' sludge would be chemically different from the sludge in the pond, having an average water content of 49%, a lower pH of 5 due to acid addition, a higher average grease content of 38%, and high zinc levels of 660 mg/kg. It would not contain organochlorine pesticides but would contain newer compounds such as diazinon and propetamphos. It is assumed that levels of zinc and dieldrin would be decreased by dilution with the addition of bulking materials, although it is appreciated, particularly in the case of zinc, that a loss of organic matter through composting would increase levels.

Conclusions

Huge volumes of waste materials are produced in the modern world. In 1990, OECD countries (the 24 most technologically advanced countries in the world) produced 9 million tonnes of municipal waste, 1.5 billion tonnes of industrial wastes (including 300 million tonnes of hazardous waste), and 7 billion tonnes of other wastes, accounting for 68% of the world's industrial waste and 90% of the hazardous/special wastes (Alloway and Ayres, 1997). It is highly unlikely that this Ashburton example is an isolated case in New Zealand. The presence of residues banned decades ago illustrates a history of poor waste management on the site. Local residents recall the colour of the wastewater discharged from the plant to the Ashburton River via the drainage channel, which reflected the dyeing of wool on that particular day.

This project demonstrated how a local consortium could work effectively together to remediate a contaminated site and produce a valuable material from the contamination. All trial partners are very positive that the requirements of NZS 4454 will be met and there will be good demand for the screened product at the conclusion of the project.

References

Alloway B J and Ayres D C (1997) Chemical principles of environmental pollution. Chapman and Hall, London.

Bateup B O, Christoe J R and Russell I M (1995) Scouring wastes: a resource, not a problem. Proceedings of the 9th International Wool Textile Research Conference.

Bateup B O, Christoe J R, Jones F W, Poole A J, Skourtis C and Westmoreland D J (1996) Effluent management. Top-Tech '96, Geelong, Australia.

Becker P, Köster D, Popov M N, Markossian S, Antranikian G and Märkl H (1999) The biodegradation of olive oil and the treatment of lipid-rich wool scouring wastewater under aerobic thermophilic conditions. Water Research, 33, 653-660.

Christian G (1998) Making sure our wool industry doesn't dip out. Wool, 8, 9-10.

EXTOXNET (1996), "DDT", Available: http://extoxnet.orst.edu/pips/ddt.htm (Accessed: 2007, September 26).
Hoffmann R and Timmer G (1996) Environmentally-friendly production of worsted tops: experiences at BWK. Top-Tech '96, Geelong, Australia.
Jones F W (1997) Supercritical fluid extraction as a cleanup technique for gas chromatographic analysis of pesticides in wool wax. Journal of Agricultural and Food Chemistry, 45, 2569-2572.
Jones F W and Westmoreland D J (1998) Degradation of nonylphenol ethoxylates during the composting of sludges from wool scour effluents. Environmental Science and Technology, 32, 2623-2627.
Jones F W and Westmoreland D J (1999) Removal of wool wax, nonylphenol ethoxylates and pesticide residues from wool scour effluent. Water Research, 33, 1775-1780.
Kroening S J (2003) Biodegradation and composting profiles of woolscour wastes. University of Canterbury, Christchurch.
Kroening S J, Greenfield L G and Williamson W M (2004) Variation in and constraints upon the decomposition of woolscour sludge. Journal of Environmental Quality, 33, 1081-1087.
Maheswaran J, Meehan B, Peverill K and Dziedzic A-M (1999), "Potential for agri-industry wastes as soil ameliorants", Available: http://www.recycledorganics.com.au (Accessed: 5.09.2001).
Ministry for the Environment (2007), "Stockholm convention", Available: http://www.mfe.govt.nz/laws/meas/stockholm.html (Accessed: 2007, September 26).
Naturefarm Limited (2007), "What is EM?", Available: http://www.emnz.com/index.php?pageid=2 (Accessed: 2007, September 27).
New Zealand Water and Wastes Association (2003) Guidelines for the safe application of biosolids to land in New Zealand. New Zealand Water and Wastes Association, Wellington.
Russell I M (1996a) Clean green wool: development of environmental regulations. Top-Tech '96, Geelong, Australia.
Russell I M (1996b) Meeting the needs on-farm: Australian program to produce low-pesticide wool. Top-Tech '96, Geelong, Australia.
Russell I M (1996c) Clean green wool: managing environmental issues. Top-Tech '96, Geelong, Australia.
Standards New Zealand (2005) New Zealand Standard: composts, soil conditioners and mulches. Standards New Zealand, Wellington.
Stewart R G (1988) Woolscouring and allied technology. Wool Research Organisation of New Zealand, Christchurch.
Wikipedia (2007), "Dieldrin", Available: http://en.wikipedia.org/wiki/Dieldrin (Accessed: 2007, September 26).
Williamson M E (1995) Pesticide residues in New Zealand wool; reducing the levels. Wool, 8, 58-60.
Williamson W M (1998) The decomposition of woolscour and fellmongery sludges. University of Canterbury, Christchurch, New Zealand.